COMPARISON OF GLOBULARISATION BEHAVIOUR DURING REHEATING TREATMENT OF DIFFERENT PEARLITIC MICROSTRUCTURES

J.P. Ferrer[1], C. Capdevila[1], F.G. Caballero[1] and C. García de Andrés[1]

[1]MATERALIA Research Group, Department of Physical Metallurgy, Centro Nacional de Investigaciones Metalúrgicas (CENIM), Consejo Superior de Investigaciones Científicas (CSIC), Avda. Gregorio del Amo, 8, 28040 Madrid, Spain. Tel:+34-91-553-89-00; fax:+34-91-534-74-25.

E-mail address: ccm@cenim.csic.es

Abstract: Pearlitic steels present very interesting mechanical properties when weldability requirements are not too severe. Thin gauge pearlitic steels require at least one intermediate annealing treatment between hot rolling and cold rolling. The globularised cementite in medium carbon steels provides then higher ductility, formability and machinability. On the other hand, in-line induction heating devices are now well known as powerful tools to reheat quickly and efficiently steel flat products. Such a reheating device induces pearlite globularisation after transformation on the run out table, and hence the conventional intermediate annealing treatment presently performed could be avoided. This work deals with the microstructural and mechanical changes that occur due to the reheating of different pearlite - ferrite microstructures simulating the conditions of an induction heating device.

INTRODUCTION

Pearlitic steels present very interesting mechanical properties when weldability requirements are not too severe. Thin gauge pearlitic steels require at least one intermediate annealing treatment between hot rolling and cold rolling. The globularised cementite in medium carbon steels provides then higher ductility, formability and machinability. On the other hand, in-line induction heating devices are now well known as powerful tools to reheat quickly and efficiently steel flat products. Such a reheating device induces pearlite globularisation after transformation on the run out table, and hence the conventional intermediate annealing treatment presently performed could be avoided.

This work deals with the microstructural and mechanical changes that occur due to the reheating of different pearlite - ferrite microstructures simulating the conditions of an induction heating device.

EXPERIMENTAL

In order to study the influence of initial microstructure on pearlite globularisation, different thermomechanical and thermal treatments were applied to a 0.44 C, 0.73%Mn 0.18%Si weight per cent steel. The pearlitic steel was manufactured using an usual austenitic hot rolling process with a finishing temperature of 850 ºC. Seven passes were performed with a total reduction of 86%. The steel was cooled down to 650 ºC at 35 ºC/s and then held in a furnace for 2 minutes in order to ensure a thermal homogeneity and the full transformation of the pearlite. After holding, the steel was air cooled. This sample was labeled as PER1. On the other hand, two different microstructures were produced after austenitisation at 1200oC during three minutes and cooling to room temperature at 0.1ºC/s (PER2) and 3 ºC/s (PER3).

Finally, a later microstructure (PER4) was achieved after hot torsion tests. After an austenitisation cycle at 1200 ºC-15 minutes the sample was deformed in five steps with a final deformation temperature of 945 ºC. Subsequently it was cooled down to 600 ºC at 50 ºC/s, held at this temperature for 20 seconds and quenched. To study pearlite globularisation, samples after hot rolling, hot torsion as well as after thermal treatments were heated at 50 ºC/s to 650 ºC and 700 ºC for 90 minutes and quenched, simulating in this way the heating by an induction heating device and the subsequent coiling.

The volume fraction of ferrite (Vf) and pearlite (Vp) was estimated by a systematic manual point counting procedure on optical micrographs. The characterisation of the lamellar microstructure of pearlite was derived from Scanning Electron Microscopy (SEM) micrographs as reported elsewhere [1].

A rigorous quantitative characterisation of the globularisation process is complex: a change in the lamellar shape of cementite, at the early stages, gradually becomes mainly a change in particle size. Tian and Kraft [2] proposed a “F” factor for the quantitative characterisation of the shape changes occurring during the globularisation process of cementite. These authors reported that such shape parameter was useful to monitor the progress of globularisation in eutectoid carbon steels.

The shape factor F is expressed as:

$$F = \frac{S_c}{3K_m} \tag{1}$$

where Sc is the specific area of cementite particles and Km is the average mean curvature. Tian and Kraft have reported a limit value of F=1 which indicates that the whole of cementite particles are spherical in shape. The actual calculation of the F values is performed in terms of the quantities NL (number of interceptions with cementite particle profiles per unit length of test line), Vc (volume fraction of cementite) and NA (number of cementite particle profiles per unit area on the plane of observation), according to the following equation [2, 3]:

$$F = \frac{2N_L^2}{3\pi V_c N_A} \tag{2}$$

Hardness measurements and tensile test were performed to characterise the mechanical properties before and after the reheating schedule. Tensile test were performed at room temperature. Deformation rate was 0.5mm/mn. No tensile tests were performed on hot-torsion samples, PER4, due to its inhomogeneous microstructure through thickness.

RESULTS AND DISCUSSION

Different microstructures with different combinations of pearlite/ferrite fraction and pearlite interlamellar spacing have been developed in the PER steel. **Table I** shows the interlamellar spacing, pearlite fraction and Vickers hardness measurements in these microstructures.

TABLE I. Pearlite characterization

Sample	% Pearlite	Interlamellar spacing (μm)	Hv (1Kg)
PER3: 1200ºC, 180s + cooling at. 0.1ºC/s	89	0.24±0.07	202±12
PER2: 1200ºC, 180s + cooling at. 3ºC/s	97	0.17±0.03	259±14
PER1: Hot rolling+ 650ºC, 2min	71	0.23±0.06	220±10
PER4: Hot Torsion + 600ºC, 10s	100	0.13±0.03	281±2

Subsequently, samples were reheated at 650ºC and 700ºC during 1.5h in order to promote the softening by pearlite globularisation. Vickers hardness measurements and SEM micrographs were performed on reheated samples. **Table II** gives the hardness measurements and the values of F after the heat treatments (**Figure 1**).

TABLE II. Samples characterization after reheat treatments

Sample	Reheated: 650ºC, 1.5h		Reheated: 700ºC, 1.5h		Hardness drop (%)	
	Hv (1kg)	F	Hv (1kg)	F	Reheated: 650ºC, 1.5h	Reheated: 700ºC, 1.5h
PER3: 1250ºC, 180s + cooling at. 0.1ºC/s	196±6	2.2±1.3	190±18	1.9±0.6	3	6
PER2: 1250ºC, 180s + cooling at. 3ºC/s	211±3	2.3±0.6	202±13	1.3±0.5	19	22
PER1: Hot rolling+ 650ºC, 2min	212±8	2.5±0.6	210±13	2.3±1.5	4	5
PER4: Hot Torsion + 600ºC, 10s	234±7	1.2±0.2	210±1	1±0.2	18	25

From **Table II** it is clear that the lower the interlamellar spacing, the higher the relative softening. Nevertheless, a lower initial interlamellar spacing means a higher initial hardness, and so, although the relative hardness drop is higher, the final value of hardness remains above values obtained in samples with an initially higher interlamellar spacing. Regarding F values, lower values are obtained after reheating finer microstructures, which involves that a more advanced globularisation stage has been reached.

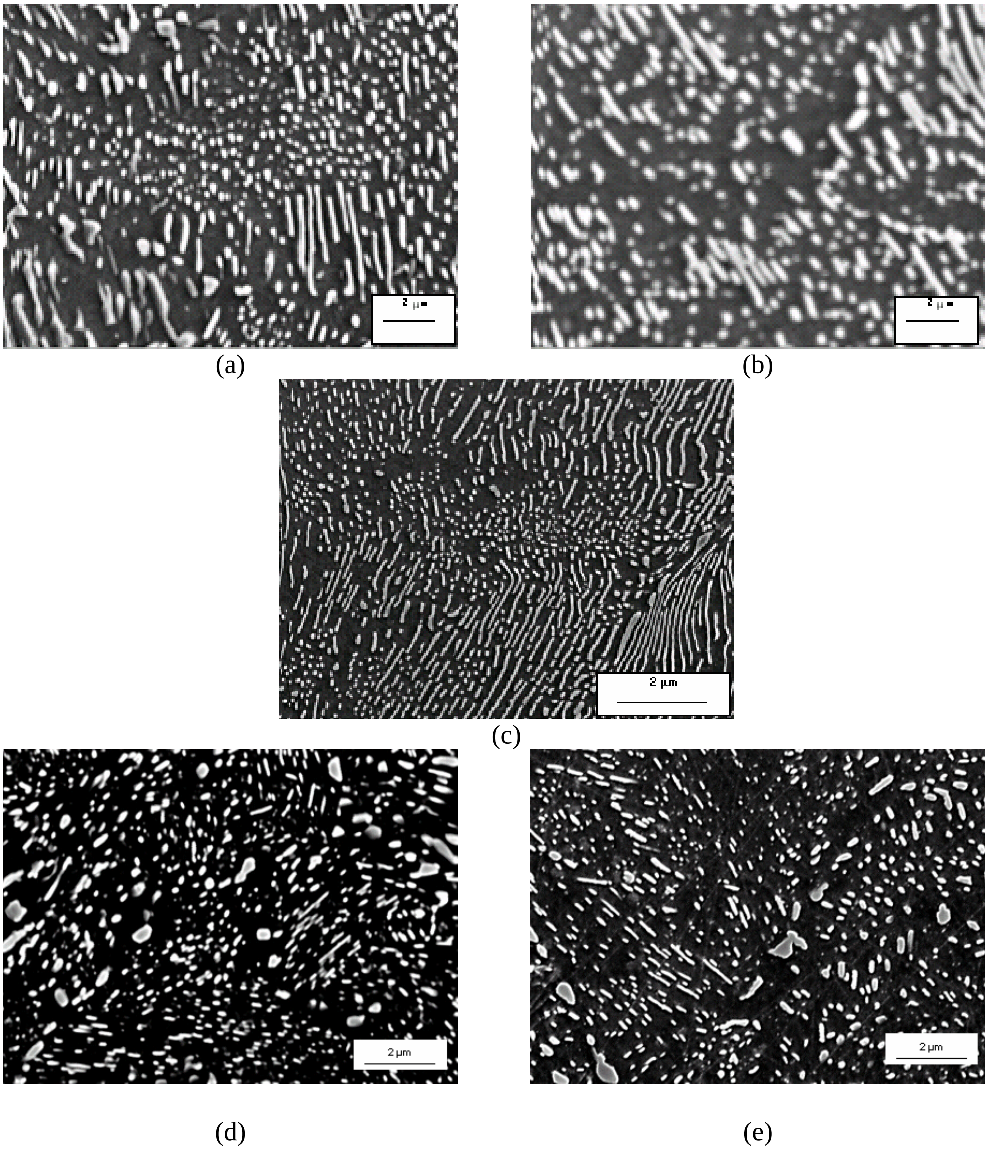

Figure 1. SEM micrographs from samples after 1.5h reheating at 700ºC. (a) CENIM. 1250ºC, 180s + cooling at. 0.1ºC/s (b) CENIM. 1250ºC, 180s + cooling at. 3ºC/s (c) IRSID: Hot rolling+ 650ºC, 2min (d) IRSID-CENIM Hot Torsion + 650ºC, 60s (e) IRSID-CENIM Hot Torsion + 600ºC, 10s.

Some tensile tests were performed in order to compare mechanical properties of different spheroidised – non-spheroidised samples **(Figure 2** and **Figure 3**).

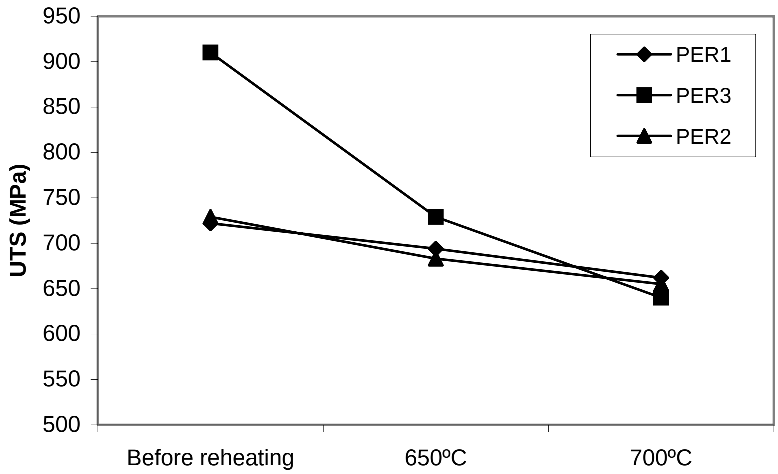

Figure 2. UTS changes with globularization

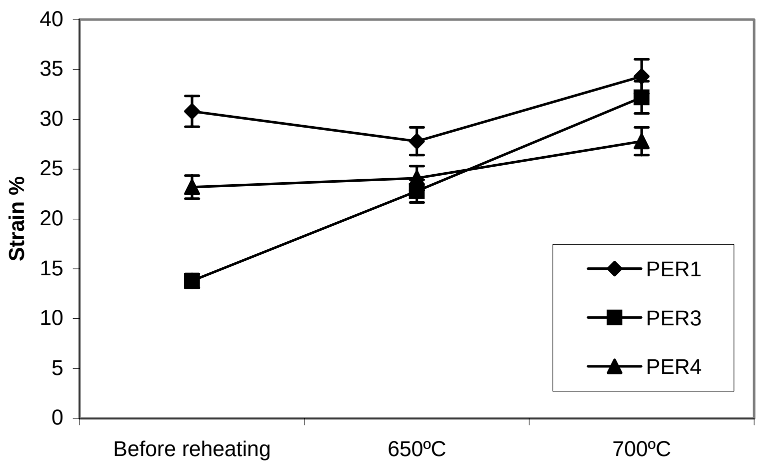

Figure 3. Elongation changes with globularisation

From the foregoing results it can be inferred that, regardless the amount of ferrite, the lower interlamellar space promotes a quicker globularisation process and hence, a more significant change in mechanical properties. Likewise, similar mechanical properties are reached after annealing during 1.5h at 700ºC the different microstructures.

CONCLUTIONS

1. The influence of different pearlite microstructures obtained by thermal or thermomechanical treatments on globularisation by simulating an induction reheating device has been studied.

2. The lower interlamellar space promotes a quicker globularisation process and hence, a more significant change in mechanical properties.

3. The value of ductility tends to overcome those obtained after the same heat treatment with a bigger interlamellar space, maintaining higher strength levels.

ACKNOWLEDGEMENTS

The authors acknowledge financial support from the European Coal and Steel Community (ECSC-7210-PR-351). J. P. Ferrer would also like to express his gratitude to MEC for the financial support in the form of a PhD Grant (FPI Program).

REFERENCES

1. F. G. Caballero, C. García de Andrés, and C. Capdevila, **45** (2000) 111.
2. Y. L. Tian and R. W. Kraft, Metallurgical transactions, **18A** (1987) 1359.
3. Y. L. Tian and W. Kraft, Metallurgical transactions, **18A** (1987) 1403.